Mg-Zn Nano Ferrite System: Synthesis and Characterisation

A

Synopsis

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1. INTRODUCTION

Magnetic materials exhibiting both electrical and magnetic properties are known as ferrites. Iron oxide and metal oxides are the main constituents of the ferrites. Ferrite materials are insulating magnetic oxides in nature and possess high electrical resistivity, low eddy current and dielectric losses, high saturation magnetization, high permeability and moderate permittivity. Ferrites are magnetic oxide materials and are semiconducting in nature**[1].** They are of great technological importance as they posses interesting electrical and magnetic properties **[2, 3].**

They find applications in transformer cores, antenna rods, memory devices, high density magnetic recording media, permanent magnets, transducers, activators, Micro waves and computer technology etc.

The ferrites in nano crystalline form found applications in new fields like magnetically guided drug delivery, magnetic resonance imaging (MRI), catalyst, humidity, photo catalysis, gas sensors, and magnetic fluids etc.**[4-6].**

The polycrystalline ferrites remain the best magnetic material which cannot be replaceable by any other magnetic materials because of their important contribution in technological applications. Therefore the processing of these materials is important in modifying the properties as per the desired applications **[7].** Ferrites contain dielectric properties. These dielectric properties mean that even though electromagnetic waves can pass through ferrites, they do not readily conduct electricity**[8].** This also gives them an advantage over iron, nickel and other transition metals that have magnetic properties in many applications because these metals conduct electricity.

Such a consideration helps us to explain why ferrites have been used and studied for several years. The properties of ferrites are being improved due to the increasing trends in ferrites technology. It is believed that there is a bright future for ferrite technology[9].

Magnetoplumbite ferrites are usually represented by $MFe_{12}O_{19}$ (M= Ba, Sr, Ca etc.) and are important in permanent magnetic applications.

The molecular formula of ferrites is $M^{2+}O.Fe^{3+}{}_2O_3$, where M stands for the divalent metal such as Fe, Mn, Co, Ni, Cu, Mg, Zn or Cd. There are 8 molecules per unit cell in a spinel structure. There are 32 oxygen (O2) ions, 16 Fe^{3+} ions and 8 M^{2+} ions, per unit cell. Out of them, 8 Fe^{3+} ions and 8 M^{2+} ions occupy the octahedral sites. Each ion is surrounded by 6 oxygen ions.

Among the different types of ferrite exhibits large applications and are widely used in telecommunication devices.

Classification of Ferrites

Ferrite can be classified into three different types

(I) Spinel ferrite (Cubic ferrite)

(II) Hexagonal ferrite

(III) Garnet

Applications of Ferrites:

Spinel ferrites ceramic are widely used in microwave devices to control transmission path, frequency, amplitude and phase of microwave signals. Accurate dielectric and magnetic property measurement at the operational frequency and temperature ranges are needed for optimized development of these devices, as well as to assist in the manufacture of the ferrite

The structured magnetic materials have an interesting area of study because of its possible applications in a variety of widely areas ranging from information technology to biotechnology **[10, 11].**

Ferrites are excellent soft magnetic materials in high-frequency devices due to their low cost, high resistivity and low eddy current losses, which have been studied extensively for multilayer chip inductor (MLCI) application. Ni-Cu-Zn ferrites have been evolved it meet a claim for the miniaturization of electronic components. Doped Zn ferrites can be utilized in multilayer chip inductor application in high frequency region**[12, 13].**

2. LITERATURE REVIEW

Mg-Zn ferrites have technology materials and find Mg-Zn ferrite have used of multilayer chip inductors and high frequency power transform cores and advanced for the power electronic applications. Mg ferrite has important used in heterogeneous catalysis, absorption, sensors and cancer treatments. Due to the magnetic important of Mg-Zn ferrite many researchers have investigated substituted Mg-Zn ferrites. The methods and dopants are the most important role in the material. $Ni1_{-x}Cu_x$ Fe_2O_4 ferrite have been recently synthesized via sol gel combustion method with single phase cubic structure and further the ferrites have been explored for structural and magnetic properties**[14].**

S. Hajarpour et al.**[15]** studies the thermal decomposition of the amount of gases temperature is rise adiabatically with the increase in fuel of oxidant and nitrates of Mg-Zn ferrite.

The substitution of Mn in Mg-Zn ferrites and then find the lattice parameter increases with increases the Mn content and decrease the coercively**[16]**.

S.G Bachhav et. al. **[17]** studies of soft ferrites with double sintering ceramic method. we have reported structural and magnetic properties to find to decrease the lattice parameter to substituted of Ni content.

A. Manikandan et al. [18] to prepare the $ZnFe_2O_4$ ferrite with structural and magnetic properties to find the behaviour of the material with the help of XRD, SEM. PL spectra etc . We have reported the saturation magnetization in the material of composition is lower the material is super paramagnetic and saturation magnetization is higher the material is ferromagnetic.

D. Narsimulu et. al. [19]studies $Mg_2Fe_2O_4$ as anode material for lithium battery applications and made to change the capacity of the lithium battery and observed the high discharge capacity due to unique meosoporous of $CoFe_2O_4$ material and high electrode lithium ion batteries.

Durani et. al. **[5]** to prepare $MgFe_2O_4$ via sol gel method and found to the single phase of the mixed spinel structure and grain size, grain boundary with the help of XRD, SEM and mossbaurimpedence spectroscopy at high sintering temperature.

M. Dhiman et al. **[20]** of magnesium ferrites with the substitution of Y and Sm via sol gel combustion method. And find the structural and magnetic properties we have reported to magnesium is important to use in potential applications in biomedical field, e.g. Hyperthermia and drug delivery etc.

3. JUSTIFICATION OF THE RESEARCH TOPIC

This topic has been chosen because of these proposed ferrites have wonderful applicative area in technology. Bare Mg-Zn and doped Mg-Zn Ferrites have been recently reported for number of applications like hyperthermia, photo catalysis and in antenna applications also. We have optimized synthesis method for the preparation of ferrites and their corresponding properties and applications also.

4. OBJECTIVES OF THE PRESENT WORK

The main objective of the present work is to synthesize two series of Ferrites.

- $Mg_xZn_{1-x}Fe_2O_4$ (x=0. 0.2, 0.4, 0.6, 0.8, 0.9, &1) ferrites nanoparticles by solution combustion method.

- $Mg_{0.5}Zn_{0.5-x}Ni_xFe_2O_4$(x=0. 0.1, 0.2, 0.3, 0.4, &0.5) ferrites nanoparticles by solution combustion method.

Synthesized materials will be characterized for structural, optical and magnetic properties.

- Structural Studies will be done using, XRD, SEM, TEM, FTIR, Raman Spectroscopy & XPS spectroscopy.
- Optical properties have been performed using UV-Visible spectroscopy.
- Magnetic properties have been performed using Vibrating Sample Magnetometer.
- Photo catalysis of toxic organic dyes will also be studied.

5. PROPOSED METHODOLOGY

Synthesis Route

The ferrite nanoparticles will be synthesized using solution combustion method using iron, nickel, magnesium, zinc nitrates and glycene as raw material. In this method, Nitrates as oxidizers and glycene as fuel/reducing agent are kept at 1:1 molar ratio and are dissolved in distilled water with the help of magnetic stirrer. The resulting solution will be heated with constant stirring at 80° C. After complete dissolution solution will be allowed to burn in open air at 120℃ resulting into fine voluminous powder. The final product will be obtained by sintering this material at some optimized temperature in muffle furnace.

Properties to be studied

Structural properties will be studied using X-Ray diffraction.

The surface morphology of the prepared ferrite nanoparticles will be analyzed using FESEM.

X-ray photoelectron spectroscope will be utilized for determination of elemental composition and binding energy.

Optical properties will be done using UV-visible spectroscopy and band gap will be calculated using Tauc's plot.

Magnetic properties will be done using recording hysteresis curves for all samples using Vibrating sample magnetometer.

6. THESIS OUTLINE

Chapter 1: Introduction

Chapter 1 **"Introduction"** includes basic introduction, history, nature, properties and various applications of nano ferrites.

Chapter 2: Literature Review

Chapter 2 **"Literature Review"** describes development and literature of concerned previous results on doped Mg-Zn Nano ferrites.

Chapter 3: Experimental techniques

Chapter 3 **"Experimental Techniques"** gives a brief description of synthesis techniques as well as the instrumentation of the experimental techniques which have been used in the present work.

Chapter 4: Results and Discussion

Chapter 4 **"Results and discussion"** presents describes the studied experimental results of structural, micro- structural, optical, and magnetic properties of prepared Nano-ferrites. The photo catalytic applications of ferrites will also be studied.

Chapter 5: Summary and Conclusion

Chapter 5 **"Summary and Conclusion"** summarizes our research work in brief and presents the major conclusions drawn from the research work.

Chapter 6: Scope of Future Work

Chapter 6 **"Scope of Future Work"** includes the major suggestions for the future scope of work in this area of research.

Chapter 7: References

REFERENCES

[1] K.K. Kefeni, B.B. Mamba, T.A. Msagati, Application of spinel ferrite nanoparticles in water and wastewater treatment: a review, Separation and Purification Technology, **188** (2017) 399-422.

[2] X. Huang, J. Zhang, S. Xiao, G. Chen, The cobalt zinc spinel ferrite nanofiber: lightweight and efficient microwave absorber, Journal of the American Ceramic Society, **97** (2014) 1363-1366.

[3] C.B.N. K, M. W, Microwave assisted solid state reaction method: Investigations on electrical and magnetic properties NiMgZn ferrites, Materials Chemistry and Physics, **181** (2016) 432-443.

[4] T. Sato, T. Iijima, M. Seki, N. Inagaki, Magnetic properties of ultrafine ferrite particles, Journal of Magnetism and Magnetic Materials, **65** (1987) 252-256.

[5] S.K. Durrani, S. Naz, M. Mehmood, M. Nadeem, M. Siddique, Structural, impedance and Mössbauer studies of magnesium ferrite synthesized via sol–gel auto-combustion process, Journal of Saudi Chemical Society, **21** (2017) 899-910.

[6] A. Arimi, L. Megatif, L.I. Granone, R. Dillert, D.W. Bahnemann, Visible-light photocatalytic activity of zinc ferrites, Journal of Photochemistry and Photobiology A: Chemistry, **366** (2018) 118-126.

[7] D. Gao, Z. Shi, Y. Xu, J. Zhang, G. Yang, J. Zhang, X. Wang, D. Xue, Synthesis, Magnetic Anisotropy and Optical Properties of Preferred Oriented Zinc Ferrite Nanowire Arrays, Nanoscale Research Letters, **5** (2010) 1289.

[8] K. Mukherjee, D. Bharti, S. Majumder, Solution synthesis and kinetic analyses of the gas sensing characteristics of magnesium ferrite particles, Sensors and Actuators B: Chemical, **146** (2010) 91-97.

[9] V.G. Harris, A. Geiler, Y. Chen, S.D. Yoon, M. Wu, A. Yang, Z. Chen, P. He, P.V. Parimi, X. Zuo, Recent advances in processing and applications of microwave ferrites, Journal of Magnetism and Magnetic Materials, **321** (2009) 2035-2047.

[10] K.J. Standley, Oxide magnetic materials, Oxford University Press, 1972.

[11] J. Jiang, L.C. Li, F. Xu, Preparation, Characterization and Magnetic Properties of PANI/La-substituted LiNi Ferrite Nanocomposites, Chinese Journal of Chemistry, **24** (2006) 1804-1809.

[12] C. Sujatha, K.V. Reddy, K.S. Babu, A.R. Reddy, K. Rao, Structural and magnetic properties of Mg substituted NiCuZn nano ferrites, Physica B: Condensed Matter, **407** (2012) 1232-1237.
[13] M. Satalkar, S. Kane, M. Kumaresavanji, J. Araujo, On the role of cationic distribution in determining magnetic properties of Zn0. 7-xNixMg0. 2Cu0. 1Fe2O4 nano ferrite, Materials Research Bulletin, **91** (2017) 14-21.
[14] H. Joshi, R. Kulkarni, Susceptibility, magnetization and Mössbauer studies of the Mg-Zn ferrite system, Journal of Materials Science, **21** (1986) 2138-2142.
[15] S. Hajarpour, K. Gheisari, A.H. Raouf, Characterization of nanocrystalline Mg0. 6Zn0. 4Fe2O4 soft ferrites synthesized by glycine-nitrate combustion process, Journal of Magnetism and Magnetic Materials, **329** (2013) 165-169.
[16] S. Mansour, Structural and magnetic investigations of sub-nano Mn–Mg ferrite prepared by wet method, Journal of Magnetism and Magnetic Materials, **323** (2011) 1735-1740.
[17] S. Bachhav, R. Patil, P. Ahirrao, A. Patil, D. Patil, Microstructure and magnetic studies of Mg–Ni–Zn–Cu ferrites, Materials Chemistry and Physics, **129** (2011) 1104-1109.
[18] A. Manikandan, L.J. Kennedy, M. Bououdina, J.J. Vijaya, Synthesis, optical and magnetic properties of pure and Co-doped ZnFe2O4 nanoparticles by microwave combustion method, Journal of Magnetism and Magnetic Materials, **349** (2014) 249-258.
[19] D. Narsimulu, B.N. Rao, M. Venkateswarlu, E. Srinadhu, N. Satyanarayana, Electrical and electrochemical studies of nanocrystalline mesoporous MgFe2O4 as anode material for lithium battery applications, Ceramics International, **42** (2016) 16789-16797.
[20] M. Dhiman, S. Rana, K. Batoo, J. Sharma, M. Singh, Synthesis and characterization of Y and Sm doped Mg nanoferrites, Integrated Ferroelectrics, **184** (2017) 151-157.

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